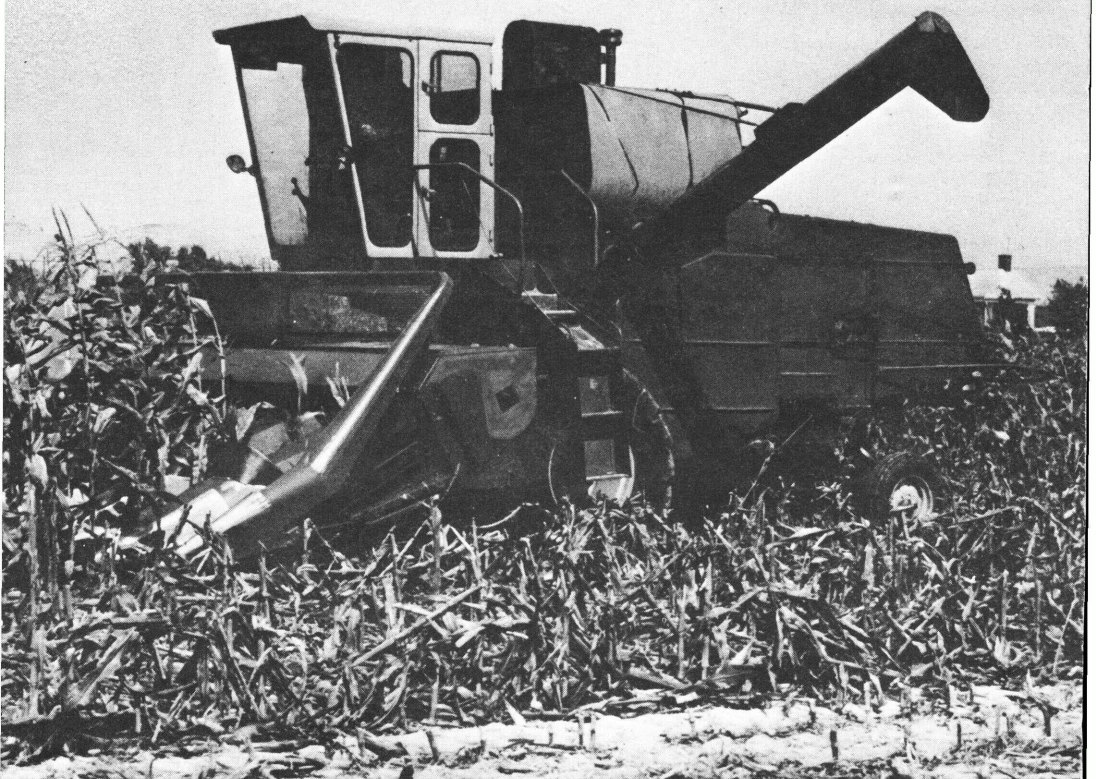
GUIDELINES FOR MOLD CONTROL IN HIGH-MOISTURE CORN



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GUIDELINES FOR MOLD CONTROL IN HIGH-MOISTURE CORN

The dramatic shift from picking corn by the ear to harvesting it with a picker-sheller or a combine is an important advance in agricultural technology.

The practice of picking and shelling high moisture corn in the field, however, does produce conditions that favor the growth of molds in shelled corn.

And molds on food and feed cause spoilage, reduce grades, and lower prices. Some molds also produce substances called mycotoxins which harm livestock and poultry. Aflatoxin is one type of these mycotoxins.

More information is needed on the nature, effects, and control of molds and mycotoxins. Research is being intensified to develop this information.

It is nevertheless possible, on the basis of information now available, to present guidelines that will help you minimize the amount of mold damage in wet corn.

The guidelines in this bulletin, and particularly the maximum storage times recommended in Table 1, are intended specifically to prevent a lowering in the grade of wet corn.

By following these guidelines, you can limit the growth of mold in corn. This, in turn, tends to reduce the undersirable effects of such growth, including the production of mycotoxins.

Let's first list the major guidelines for preventing moldy corn. Then we'll go into more detail on how it's done.

- Reduce the moisture and temperature of shelled corn whenever possible. Recognize that high levels of moisture and temperature, together with damage to kernels, are the chief reasons for the growth of molds in shelled corn. Mold growth is negligible when corn moisture is below 13 percent. Temperatures below 40° F. will slow the growth of most molds, although some grow even at or below freezing.

- Never exceed the maximum storage time for a given combination of moisture and corn (or air) temperature (Table 1). Remember that these maximum times begin with harvest.

- Dry wet corn to 12 to 14 percent moisture immediately after harvest. This is the surest method of limiting mold growth.

- *If you must* hold wet corn at moisture levels above 20 percent—without even a small amount of drying—maintain corn temperatures as low as possible under aeration. If you are using refrigerated air, keep

TABLE 1.—*Maximum time for storage of shelled corn at various corn moisture and air temperatures.*[1]

Storage air temperature (fahrenheit)	Corn moisture content			
	15%	20%	25%	30%
	Days	*Days*	*Days*	*Days*
75°	116	12.1	4.3	2.6
70°	155	16.1	5.8	3.5
65°	207	21.5	7.8	4.6
60°	259	27	9.6	5.8
55°	337	35	12.5	7.5
50°	466	48	17	10
45°	725	75	27	16
40°	906	94	34	20
35°	1,140	118	42	25

[1] The times given are those above which mold growth will cause enough loss in corn quality to bring about a lowering of grade.

Storage under recommended conditions of temperature, moisture, and time does not guarantee the absence of mycotoxins, substances produced by certain molds. Mycotoxins in feed can be harmful to livestock and poultry.

the maximum temperature between 28° and 34° F.

Here are other major guidelines:

- Follow those cultural practices most likely to produce a vigorous corn crop and make it fully mature before cool weather. If corn fully matures within the growing season, there is less infection and mold growth while ears are still on the plant.

- Keep damage to kernels to a minimum. Causes of damage include: high-moisture shelling; improper adjustment of combine or picker-sheller; high-speed operation of combine, picker-sheller, or loading and unloading equipment; and insect damage in the field and in storage.

- Use caution in blending lots of corn that differ substantially in either quality or moisture content, as described on page 7.

- After the corn has been dried to a moisture level adequate for storage, provide airflow sufficient to bring it to a uniform temperature of 40° F. or below.

- Check corn regularly for moisture, heat, mold, insects, or off odors.

- Follow good sanitation practices and good insect-control and disease-control practices.

WET SHELLED CORN—A SPECIAL PROBLEM

The practice of using combines and picker-shellers results in shelled corn with high moisture content.

The higher the moisture, moreover, the greater the amount of me-

chanical damage to kernels during shelling.

The portion of today's crop being shelled in the field is large and growing. It is harvested fast, in a much shorter time span than in the past. And it must be dried promptly or held under suitable conditions until it can be dried.

The molds that infect corn are present everywhere. Eliminating them is virtually impossible, without chemical fungicides in extreme high temperatures. You can control them, however, through good sanitation practices, careful harvesting, and proper management of drying, holding, and storage processes.

In handling your corn, consider these facts developed from Table 1:

(1) At any given temperature, you can hold corn having 15 percent moisture nearly 10 times as long as 20-percent corn, about 27 times as long as 25-percent corn, and roughly 45 times as long as 30-percent corn.

(2) You can hold or store corn of any given moisture content at 35° F. nearly 2½ times as long as at 50° F., over 4 times as long as at 60° F., and nearly 10 times as long as at 75° F.

(3) You can hold corn that has not been physically damaged 2½ times as long as field-shelled corn regardless of the moisture and temperature.

HARVESTING

Harvest Time

There usually are economic advantages to starting harvest early.

But you should recognize that an early harvest is accompanied by conditions that favor rapid mold growth —generally higher air temperatures, higher moisture content in your crop, and more kernel damage.

The same conditions threaten your corn with loss of condition and grade —and a substantial drop in price— unless the crop is dried or aerated promptly.

Harvest your corn only as fast and only at such moisture levels as can be handled with available drying and aeration equipment.

Don't wait until the corn is picked and then look for a way to avoid trouble. Be prepared for the harvest by having—

- An adequate drying or aeration system.
- Adequate sealed corn storage.
- Provisions for prompt feeding to livestock.
- Reasonable assurance of a ready market for wet corn.
- A workable combination of these safeguards.

Harvest Damage

Mold readily invades damaged kernels. It penetrates chipped, cracked, or crushed seed coats and feeds upon the energy stored in the kernels.

Corn shelled mechanically at 28 percent moisture can be damaged severely. It is not unusual for 25 to 35 percent of the kernels to have visible damage. By comparison, tests show that carefully hand-shelled, 28-percent corn has between 1 and 2 percent mechanical damage.

The heavily damaged corn will deteriorate from two to five times as fast as kernels that were hand shelled.

You should make every effort, therefore, to keep breakage to a minimum during mechanical shelling.

Check your corn periodically during field shelling for breakage and damage. Examine the kernels carefully; some damage is not readily apparent.

If breakage is heavy, your combine or picker-sheller either needs adjustment, or it should be operated at a slower speed. Top speed is usually too fast for high-moisture corn.

DRYING

Heated-Air Drying

The use of heated-air drying has been greatly stepped up in most areas because of the urgent need to handle the crop faster.

The capacity of a drier varies, of course, with the moisture content of the corn and with the drying temperature used.

High drying temperatures increase capacity, but they may also damage the corn.

In batch drying, the intended use of the corn may determine the selection of a drying method.

Intended use also determines the permissible drying temperature:

- Corn dried with air temperatures above 130° to 140° F. is inferior for many uses because of increased surface checking and internal cracking of the kernels. Such corn is not suitable for the general market even though the buyer may be unable to detect the damage immediately.
- Corn to be fed to livestock may be dried at temperatures ranging between 180° and 200° F. with little loss in nutritive value.

The information in Table 1 makes it possible to determine the drying capacity needed to handle a given corn crop at a given rate of harvest.

Let's set up a sample corn harvest by way of illustration. Assume that:

—The crop consists of 500 acres of corn yielding 90 bushels per acre, or a total of 45,000 bushels.

—All of the corn will be field-shelled at 25 percent moisture.

—It will be harvested at a rate of 500 bushels per hour, 10 hours a day.

—The warm, early fall weather will have temperatures around 65° F. during the day and 45° F. at night.

—Aeration will be available which can provide air at a rate of 1 cubic foot per minute per bushel. Twelve hours will be required to reduce each day's harvest—5,000 bushels—from 65° to 45° F.

Table 1 shows that the maximum safe storage time for 25 percent corn is 7.8 days at 65° F. and 27 days at 45° F.

Since the corn will be at 65° F. for 12 hours, you will have used up half a day of your safe storage time. This half day is 6 percent of the 7.8 days of safe storage available at 65° F

$$\frac{0.5}{7.8} \times 100 = 6\%$$

The storage time at 45° F. is 27 days. The time left at 45° F. then, is 25 days (94 percent of 27 days).

Thus 25 days after the last corn is harvested, it should all be dried. Adding 9 days harvest time brings the total allowable time to 34 days —from beginning of harvest until all corn has been dried.

An adequate drying system, therefore, must be able to dry the 45,000

bushels in 34 days, or at a rate of 1,323 bushels per day. Where a continuous-flow drying system is used, the rate should be 55 bushels per hour.

At the end of the 9-day harvest operation, some 12,000 bushels will be dry, and 33,000 bushels will require aeration until dried.

Nine 5,000-bushel bins will provide storage for the entire crop.

The preceding example assumed ideal harvesting conditions. Frequently in Iowa, October temperatures do not go below 50° F. for periods of 3 or 4 days. A more realistic design would allow for this unfavorable weather. Proper management, therefore, requires constant adjustment to match the drying to actual weather conditions.

Let's continue the computation of the example to determine the needed British Thermal Unit (B.t.u.) rating of the drier.

A heated-air, continuous-flow drier must remove 8.65 pounds of water per bushel to dry corn from 25 percent to 13 percent.

To dry 55 bushels per hour, it must remove 476 pounds of water per hour (55×8.65).

The evaporation of 1 pound of water requires about 1500 B.t.u. of heat energy, allowing for the inefficiency of the drying process.

The drier, therefore, should have a rating of 714,000 B.t.u./hr. (476×1500).

The temperature of grain does not reach the temperature of the air being forced through it during heated-air drying; but, at the completion of drying, the corn nevertheless is too warm for unventilated storage.

CAUTION

Use care in blending lots of corn that differ substantially in either quality or moisture content.

Do not, for example, blend "good" corn with "bad" corn in the belief that the good will slow the rate of deterioration and/or mold growth in the bad.

It will not.

The poorer corn will deteriorate at the same pace as though corn of higher quality were not present.

Moreover, the overall mixed batch, including the good corn, stands to lose in grade as mold and deterioration proceed.

Similarly, do not blend corn of 20-percent moisture content with 10-percent corn in the belief that the mixed batch will equalize overall at 15 percent.

It will not unless the mixing is unusually thorough.

You may have a safe average moisture content, but this does not help the portions of any batch of mixed corn that remain above the average.

Make sure that the moisture content of the wettest kernels in any portion of the lot does not exceed the desired level to which you are drying your corn.

The corn can be moved from the drier to a temporary holding bin, where it is tempered and cooled, as discussed in the section on dryeration on page 13. Dryeration, incidentally, solves the problems of brittleness and

overheating sometimes encountered in heated-air drying.

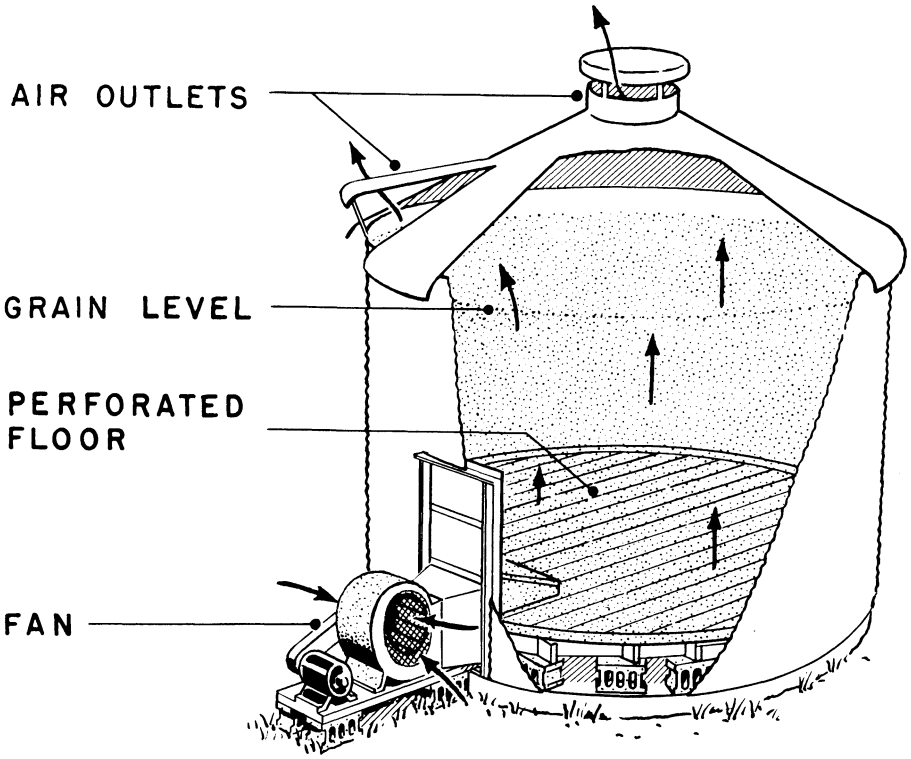
Or the corn can be moved directly to a permanent storage bin equipped for aeration. The bin should be filled in a way that distributes fine trash throughout. The corn must then be aerated continuously until all of it reaches the temperature of the outside air. Use a downward airflow when cooling corn to avoid the possibility of condensation at the top of the bin.

For complete information on drying systems, write for Farmers' Bulletin No. 2214, "Drying Shelled Corn and Small Grains." Send a postcard request to Office of Information, U.S. Department of Agriculture, Washington, D.C. 20250. Include your ZIP Code.

Unheated-Air Drying

You can dry wet corn to a satisfactory moisture level in most climates of the United States by ventilating it with unheated air.

But you must supply an adequate volume of air to dry the entire lot of corn within the appropriate safe storage time. Besides drying the grain, an



Circular metal bin with false floor of perforated metal.

adequate flow of air prevents respiration—natural "breathing" of the grain—from raising the temperature of the undried corn.

Bins with perforated false floors are recommended for unheated-air drying Air is blown up through the grain from beneath the floor.

The required airflow depends on the moisture level of the corn, its depth in the bin, weather conditions, and the amount of mechanical damage to the corn. The required airflow at various moisture contents and at practical corn depths is shown in Table 2.

Supplemental-Heat Drying

You will find that the recommended airflow volumes for unheated-air drying (Table 2) are usually adequate to prevent molding or other damage.

During some years, this airflow will not be adequate, because the humidity remains unseasonably high. By adding "supplemental heat," however, you usually can overcome these adverse conditions.

Supplemental heat is used to increase air temperatures 10 to 20 degrees during part or all of the pe-

TABLE 2.—*Fan requirements for drying shelled corn unheated air from different percentages of moisture content and at various practical depths.*

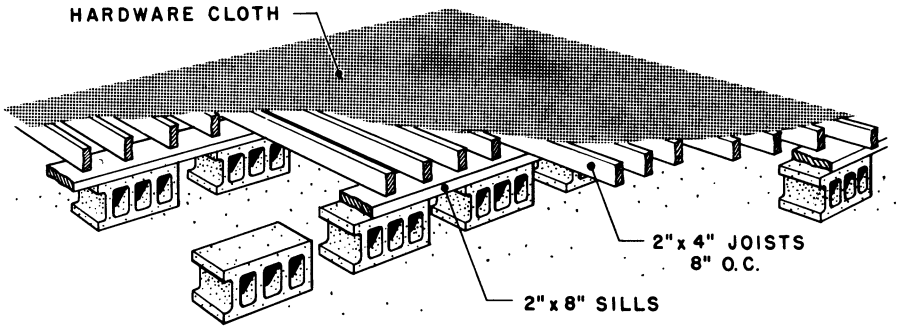
Moisture content (percent)	Recommended minimum airflow rate per bushel [1]	Practical depths [2]	Static pressure [3]	Maximum quantity that can be dried per fan horsepower [4]
	Cubic feet per minute	Feet	Inches, water gage	Bushels
25	5	4	0.7	860
		6	1.6	380
20	3	6	.9	1,120
		8	1.5	670
18	2	6	.6	2,500
		8	.9	1,670
		12	2.2	680
16	1	8	.5	6,000
		12	1.0	3,000
		16	1.6	1,880

[1] Increase 20 percent in southeastern United States.

[2] Layer drying (page 10) is a method by which these recommended corn depths may be increased.

[3] Static pressure includes 0.25-inch allowance for loss from duct friction.

[4] Airflow of cubic feet per minute (c.f.m.) per horsepower based on 3,000 c.f.m. of air at 1-inch static pressure.



Hardware cloth used as a false floor in a bin.

riod required for drying in storage. The atmosphere supplies a substantial portion of the heat for drying.

With batch drying, on the other hand, virtually all the heat is supplied by fuel.

The buildings and the fan and duct systems are similar for drying both with unheated air and with supplemental heat.

The supplemental heater is usually a relatively small liquefied petroleum (LP) gas burner or a natural gas burner. Select a burner with the capacity to raise air temperatures 10 to 20 degrees when the fan is delivering its normal volume.

You may control the supplemental heater either manually or automatically. The automatic types are controlled by humidistats, thermostats, or time clocks. Some of the automatic units modulate; others switch on and off.

These controls permit you to (1) prevent excessively high temperatures in drying corn; (2) avoid overdrying lower layers, those nearest the source of heated air; and (3) conserve fuel.

With supplemental heating, the lower layers of corn tend to become drier than is necessary for safe storage.

Loss of moisture reduces weight. If you intend to sell the corn soon after drying, you will lose money by overdrying.

But if you intend to keep it in storage, some overdrying may be an advantage, particularly in the South or other areas where insect infestation is a severe problem.

Overdrying early in the drying period may also be used to your advantage if the drying is finished with unheated air. The overdried grain will absorb moisture from incoming forced air and increase the drying potential for the undried grain in the layers above.

Layer Drying

Layer drying allows you to dry corn with unheated air to depths greater than those recommended as "practical" in Table 2.

Without layer drying, the power

requirements for ventilation rise steeply as corn depth increases; and the cost of deep-storage drying becomes prohibitive.

Yet if you stay within the recommended depths, you may limit yourself to uneconomical use of your storage bins.

Layer drying is a middle course. It consists of drying corn in successive layers of moderate depth. It keeps costs reasonable while permitting full use of storage bins.

The depth of each layer and the time for drying each layer depend on the corn moisture, the bin diameter, and the fan size.

Most manufacturers of grain drying bins and drying fans recommend layer drying systems for the equipment they produce.

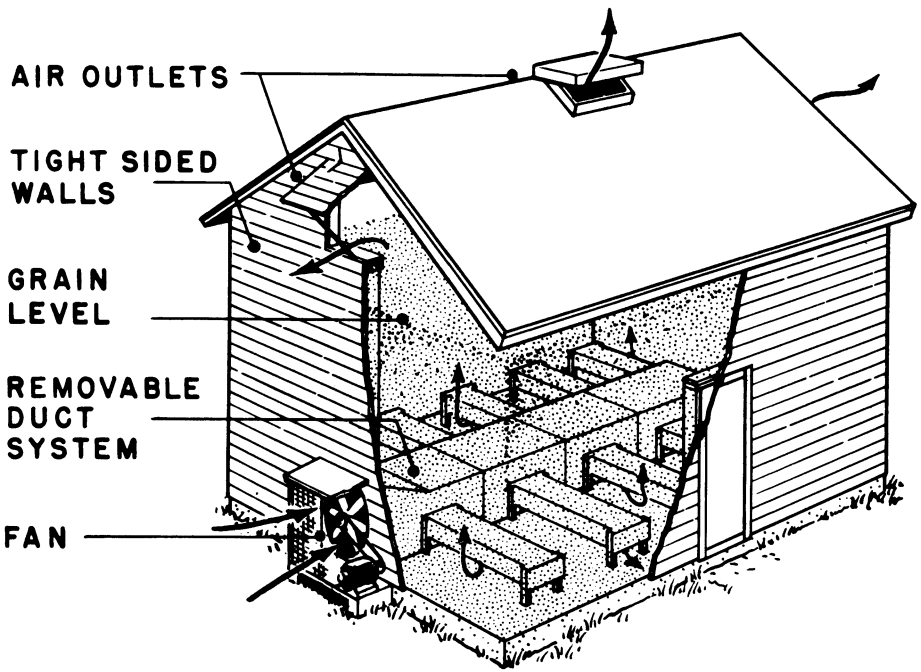
Since the airflow is from bottom to top, the drying front will also move through the corn from bottom to top. For best results, add each layer just before the drying front reaches the surface of the corn already in place.

The simplest way to find the drying front is to push a smooth stick or pipe into the corn from the top. When it reaches the drying front, it will begin to penetrate much more easily than it did when pushing through undried corn.

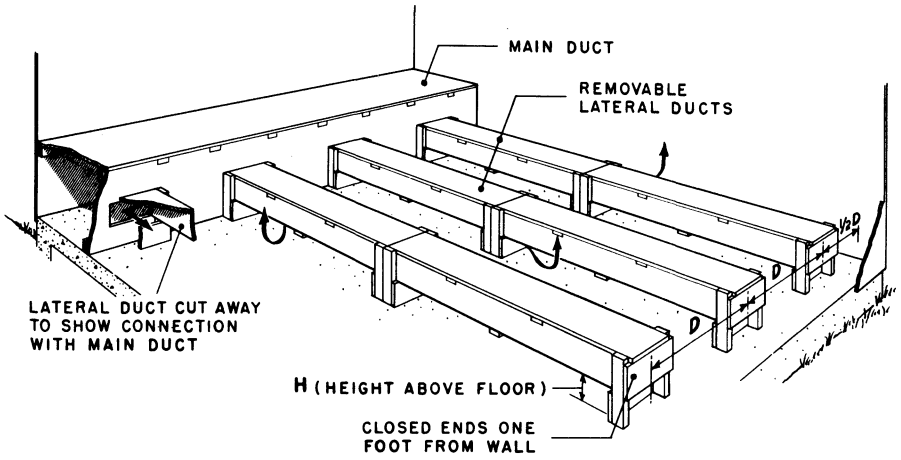
AERATION

Aeration has been used for many years to maintain the condition of dried corn in storage.

It is also being used today to hold wet corn for short periods until drying facilities are available.



Rectangular bin with duct system.



Details of duct system for drying bin.

Aeration lowers temperature. It does not reduce moisture substantially.

For best results from the aeration of wet corn, make the greatest use of cool night air. You should aerate whenever air temperature is lower than the maximum grain temperature.

At an airflow rate of 1 cubic foot per minute per bushel, the grain can be reduced to night temperatures in about 12 hours. Sunset to sunrise is long enough.

To guard against trouble during aeration:

- Be prepared to adjust your schedules in the event of abnormal weather.
- Make sure you are circulating enough air.
- Make sure the circulation is uniform throughout the holding area or storage.
- Recognize that your corn will have substantially less potential for further storage once it has been held under aeration even if molding is not evident (Table 1).

Refrigerated Aeration and Storage

Refrigerated aeration and storage systems, relatively new developments in this country, are being tested as still another means to delay spoilage of high-moisture corn.

Refrigerated systems can function day or night when outside air temperatures are too high for chilling by conventional aeration.

You can chill and hold wet corn for a limited time without excessive mold growth if you keep the maximum temperature between 28 ° and 34 ° F.

Once you remove the corn from refrigerated aeration or storage, how-

ever, it is important that you dry it promptly by established methods, feed it wet to livestock, or process it.

The principal effect of chilling is to reduce temperature, but some drying does occur if chilled air is controlled properly.

The effect of long-term chilling on grain quality is being studied.

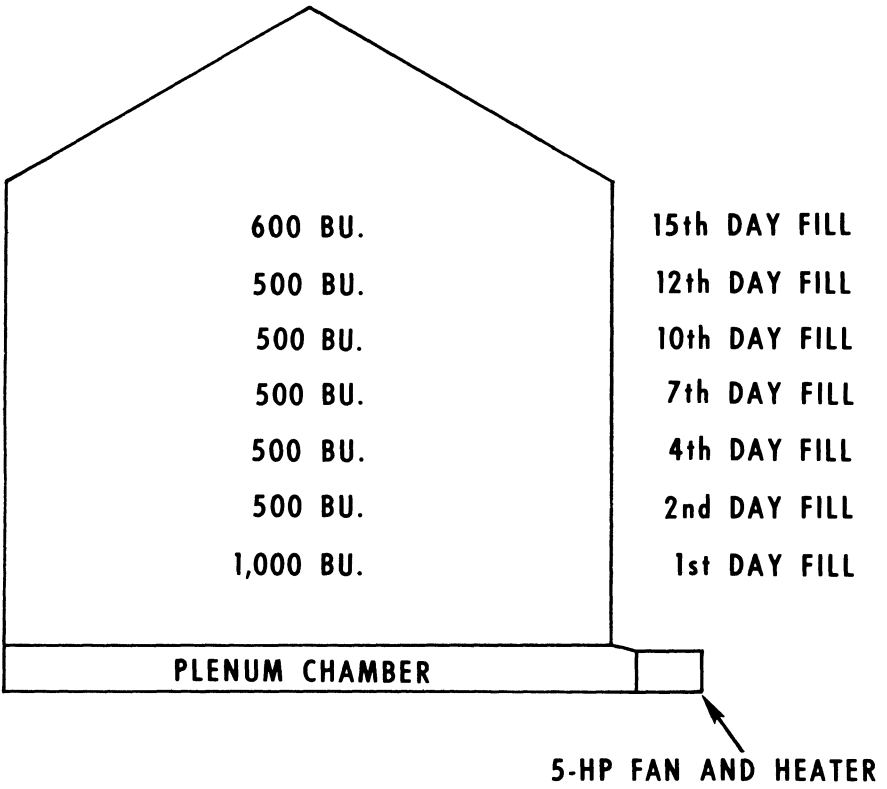
The milling quality of corn with a moisture content of 30 percent or above may be reduced if it is frozen at temperatures below 28 ° F.

Dryeration

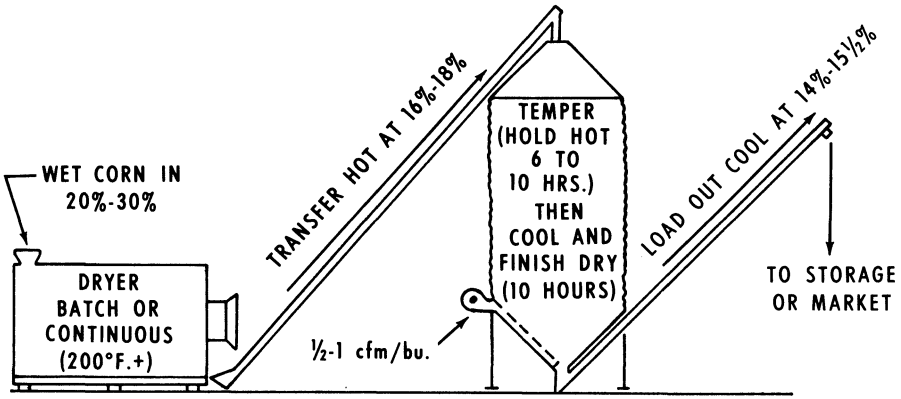
Dryeration meets two of the major problems of conventional heated-air drying—overheating and brittleness. And it greatly increases the capacity of conventional dryers.

Tests have shown that dryeration maintains the milling quality normally destroyed by overheating, and that it halves the number of stress cracks normally formed during rapid heating and rapid cooling.

Dryeration combines rapid drying



Filling rates for instorage layer drying of shelled corn having 25 percent moisture. The bin is 21 feet in diameter and has a capacity of 4,100 bushels. The supplemental heater unit is equipped with a 5-horsepower fan; humidistat is set at 55 percent.



Schematic flow diagram of the dryeration process. Wet corn is placed in the dryer from a holding bin or transport vehicle. After drying, corn is transferred hot to the dryeration cooling bin. Corn is accumulated without cooling for approximately 4 to 10 hours for tempering, then cooled slowly. Slow cooling takes approximately 10 hours and reduces moisture about 2 percent. Grain is unloaded cool and dry.

and aeration and can be adapted to either batch or continuous-flow drying systems. It was developed by engineers of USDA and Purdue University.

The dryeration process includes three basic steps:

(1) Corn is dried until it reaches a moisture level of about 16 percent. The air used has a temperature of 200 ° F. and above. The corn itself will remain relatively cool at a 16-percent moisture level.

(2) The corn is transferred immediately without cooling to a temporary storage bin equipped for aeration. It is allowed to temper 4 to 6 hours so that kernels can equalize in moisture. Then it is aerated at an airflow of 1/2 to 1 cubic foot per minute per bushel. The desired cooling is completed in 8 to 12 hours. Moisture is reduced 1 to 2 percentage points.

(3) The next morning, the cooled corn is moved to storage or market to make room for more hot corn dried to about 16 percent moisture.

Dryeration increases drying capacity by using higher air temperatures and by eliminating the cooling period in batch drying. It also releases that part of the holding capacity of continuous-flow dryers normally used for cooling.

Emergency Measures

For information on plastic-sheet aeration or other emergency measures that might be taken when available drying or storage capacity is exhausted, see your county agricultural agent or contact your State agriculture experiment station.

For further information, see AE72, "Dryeration, Better Corn Quality with High-Speed Drying." You may obtain a copy by sending 20 cents to the Extension Bulletin Editor, AES Building, Purdue University, Lafayette, Indiana 49707. Include your ZIP Code in your return address.

STORAGE

Conventional Storage

You can store shelled corn successfully as dry corn or for short periods as high-moisture corn. However, you must observe the maximum storage times (Table 1) regardless of the type of storage you use.

In computing allowable time for storage, be sure to take into account any portion of that time which was used up during drying or aeration—that is, any portion used between harvest and the time storage began.

Be sure to distribute corn uniformly while filling the bin. This will help eliminate pockets of fine trash, which are both collecting points for insects and a common source of spoilage. Good distribution can best be accomplished with a good mechanically powered spreader.

Provide adequate aeration.

Aeration is adequate when it keeps temperature and moisture at safe levels throughout the storage bin.

Without adequate aeration, important differences in temperature build up at separate locations. Moisture may then concentrate at damaging levels in the colder spots.

The problem is aggravated when large masses of grain are stored, when there are drastic changes in the weather, and when storage is of long duration.

Check all storages every 30 days in cold weather and every week in warm weather for any increase in temperature or moisture and any sign of mold or insects.

Make sure your bins are weathertight. Small leaks can cause serious damage to your crop.

Airtight Storage

As a practical, economical alternative to conventional storage, you can place high-moisture corn in sealed, airtight storage on the farm and use it for livestock feed.

Corn so stored is virtually never moved in the commercial market.

Air is excluded from the storage by means of tight construction.

Close the storage building immediately after filling. Any oxygen present is promptly used up and replaced in the course of normal respiration.

Molds cannot grow without oxygen. But other organisms known as anaerobes remain active and, by process of fermentation, transform the corn into desirable feed.

Many structures which provide airtight storage permit you to unload without opening the storage bin.

You may use conventional silos for sealed storage if you make them airtight. Once you open them, however, you must unload fast enough thereafter to prevent spoilage of surface corn as it is exposed. Shelled corn stored in this manner should have at least 25 percent moisture to permit adequate bacterial activity and fermentation.

SANITATION

Poor sanitation is yet another contributor to corn spoilage. Here are some sanitation safeguards you should follow:

- Use good insect control practices at all times.
- Remove excessive foreign matter.
- Make sure that all storage areas, including temporary ones, are clean.
- Do not mix "clean" corn with spoiled corn, with visibly moldy corn, or with corn which has suffered heavy damage of any type.
- If any part of the crop has lodged or otherwise been exposed to mold, handle and store it separately.

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